High Solids Anaerobic Digestion for Energy and Nutrient Recovery

Washington Bioenergy Research Symposium

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Center for Sustaining Agriculture and Natural Resources
Department of Biological Systems Engineering

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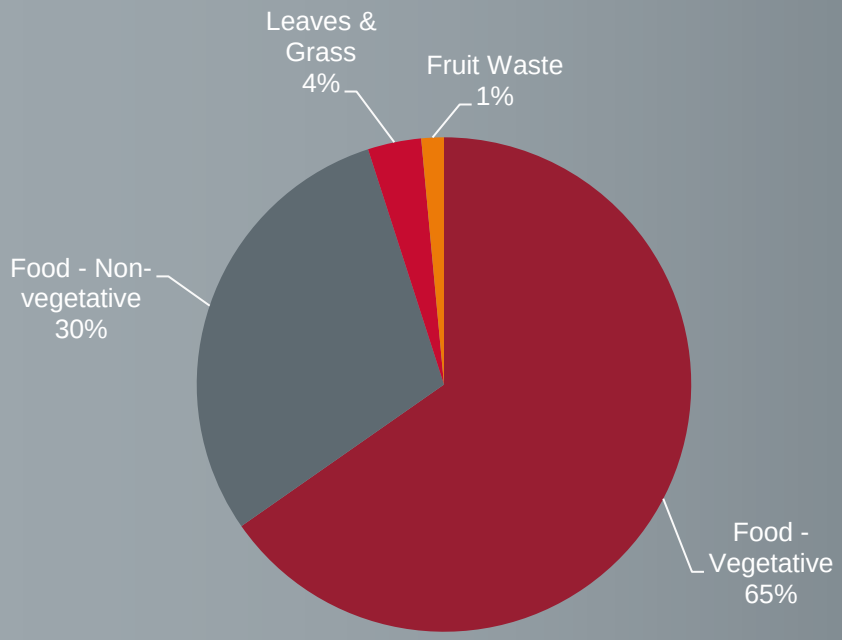
U.S. Energy Consumption

- 100 quadrillion BTUs of total energy is consumed annually, with 26% imported.
- The food production chain accounts for 16% of annual consumption
- Unfortunately within this chain there exists considerable waste, 1995 national estimate is at 27%
- Various waste treatment and disposal processes require an additional energy input estimated at 2% of annual consumption

Washington Waste Characterization

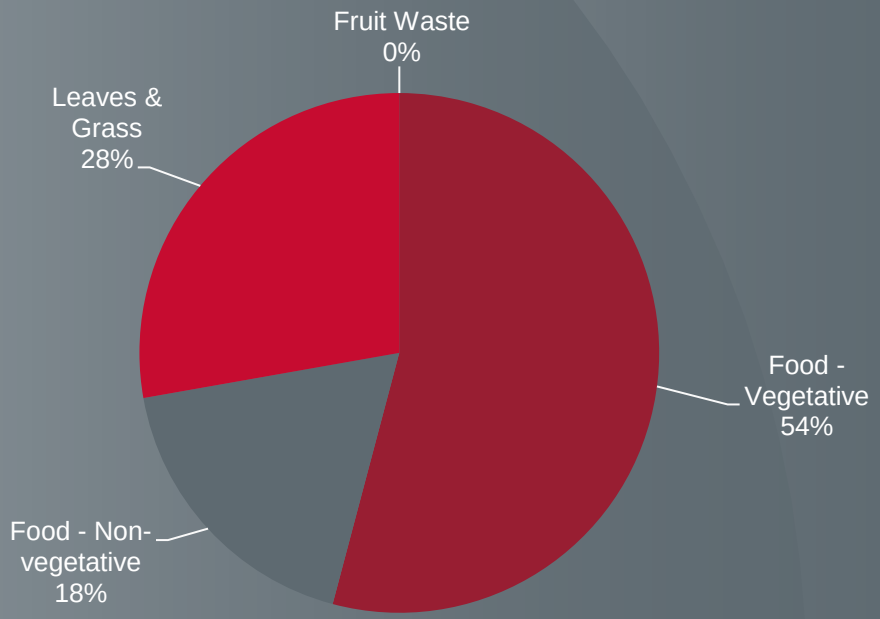
2009 Washington Statewide Waste Characterization Study has determined that 27.2% of the disposed waste stream was organics, with commercial and residential streams composed of 23.9% and 41.2% organics, respectively.

Commerical



Annual tonnage: 502,090

Residential



Annual tonnage: 573,284

Anaerobic digestion of this biomass has the potential to produce enough energy to power 25,000 homes per year

Economic and Environmental Advantages of AD for the Treatment of Food Waste

Treatment	Costs ($/MT)	Net Costs ($/MT)
Collection + Landfill	140	140
Collection + Incineration	200	180
Collection + Composting	170	170
Collection + Anaerobic Digestion + Composting*	165	50

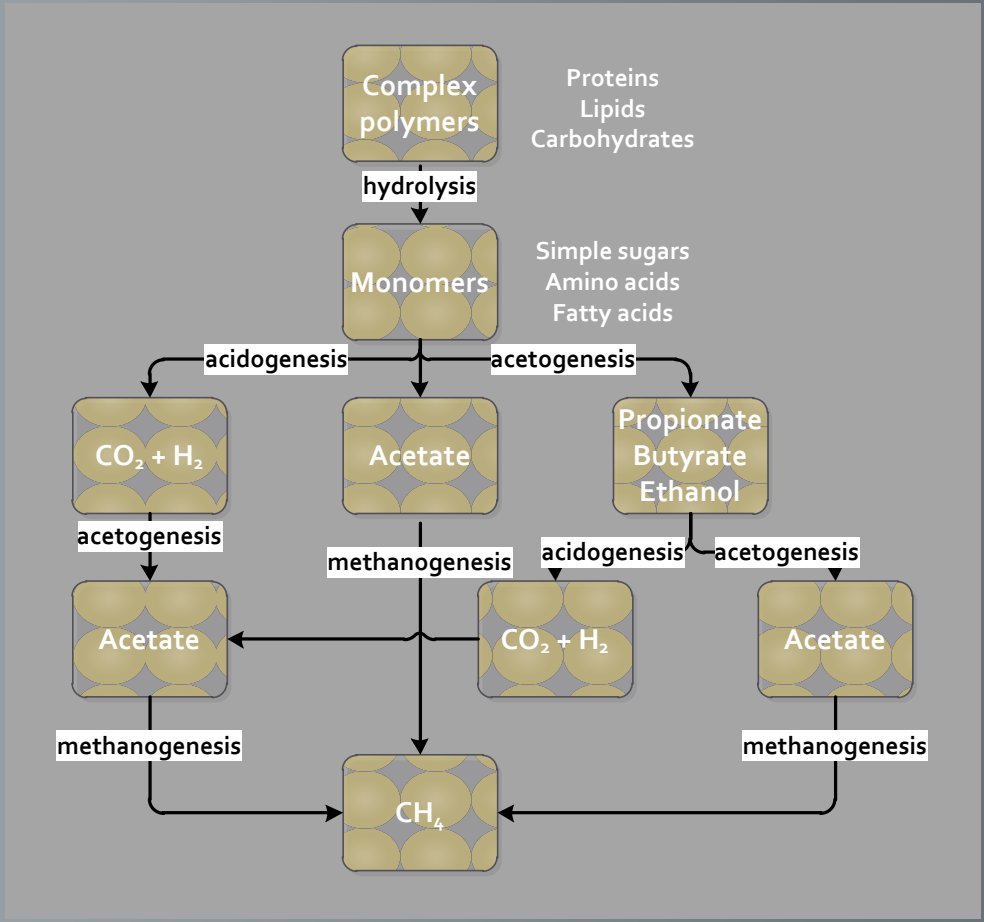
Diggelmann, Dr. Carol and Dr. Robert K. Ham. Department of Civil and Environmental Engineering – University of Wisconsin. January 1998. “Life-Cycle Comparison of Five Engineered Systems for Managing Food Waste.”

Volatile Compounds	Composting (g/MT)	Composting after Anaerobic Digestion (g/MT)	Percent Reduction
Total VOC + NH_3	747	101	86%

J. Mata-Alvarez , S. Mace, P. Llabres . Anaerobic digestion of organic solid wastes: An overview of research achievements and perspectives Department of Chemical Engineering, University of Barcelona, Martõ i Franques 1, Plta. 6, E-08028 Barcelona, Spain Accepted 24 January 2000

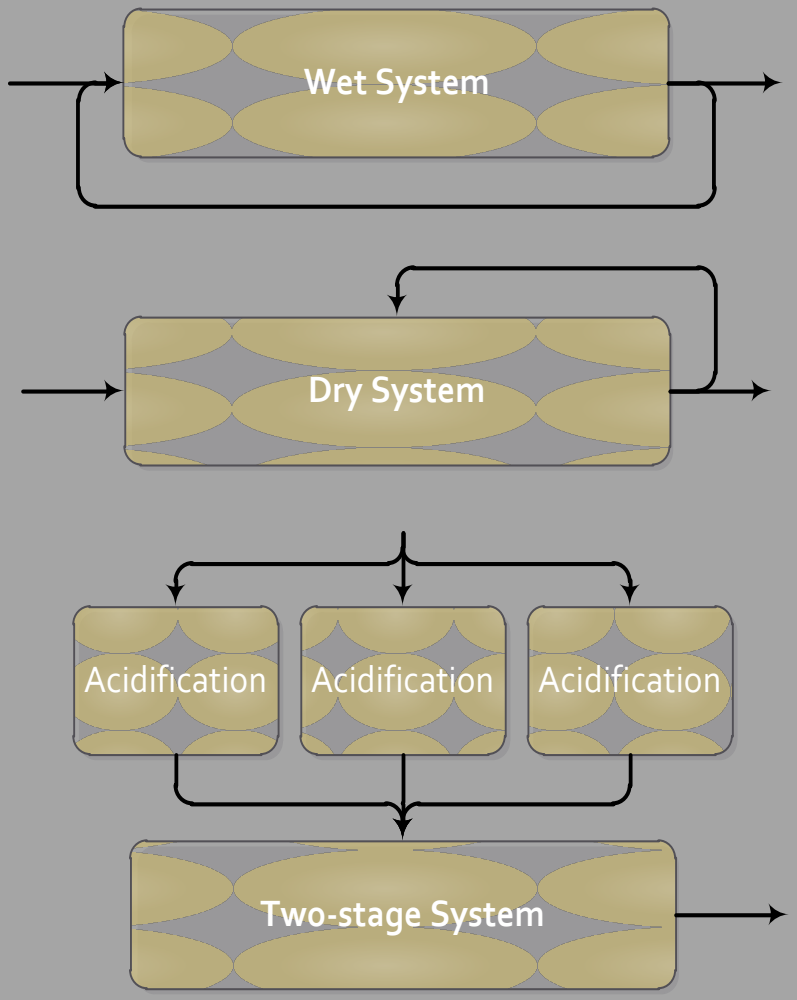
AD Process

- AD uses natural, mixed microbial communities in an oxygen free environment at controlled temperature to stabilize organic waste while producing methane rich biogas



Bitton G. *Wastewater Microbiology*. John Wiley & Sons, Inc., 2005.

AD Approaches Suitable for Food Waste Treatment

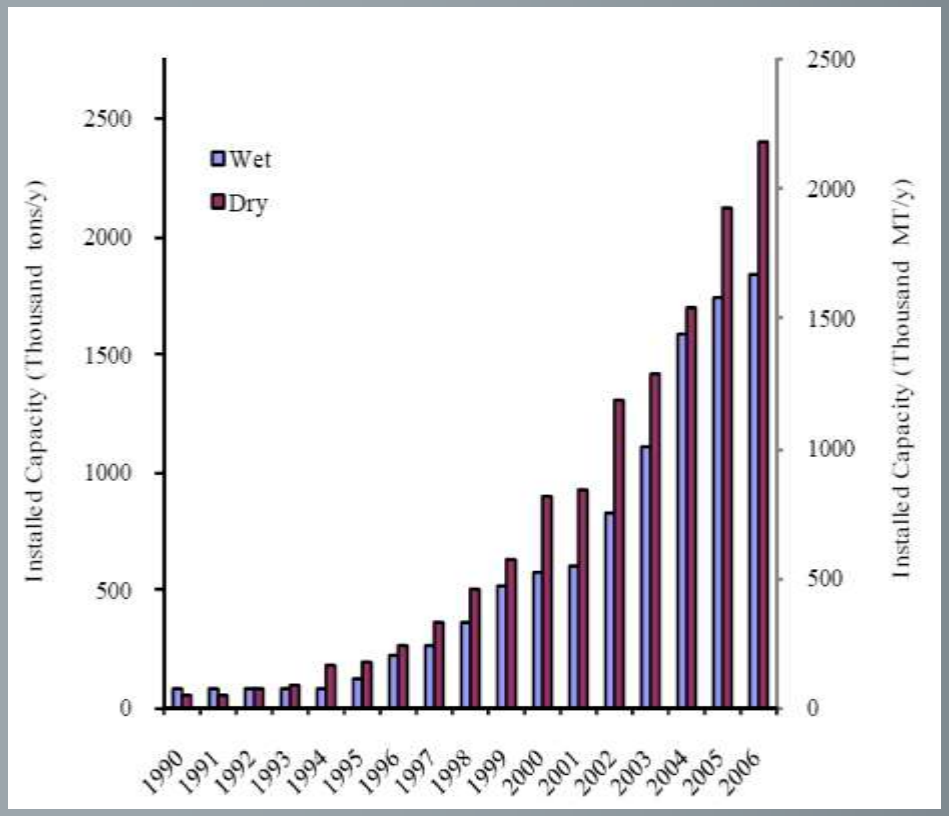


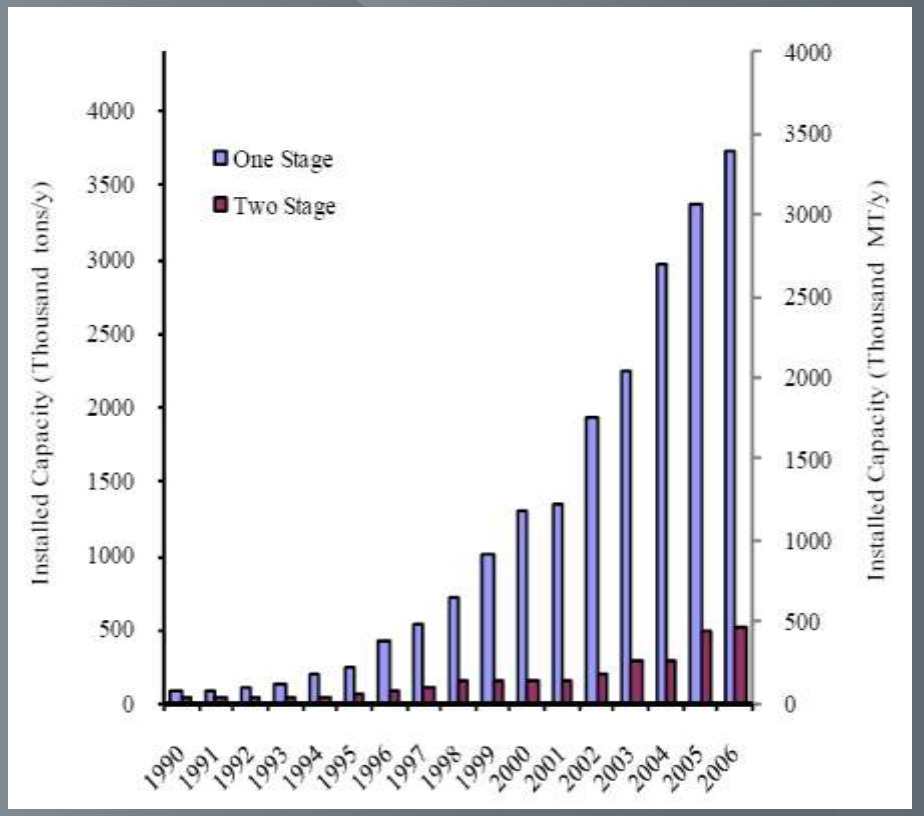
- Intensive solids recycle
- High water utilization
- Susceptible to VFA inhibition

- Mass transport limitations
- Low microbial activity
- Extended solids retention time

- Multiple reactors
- High capital costs
- High water utilization
- pH control needed

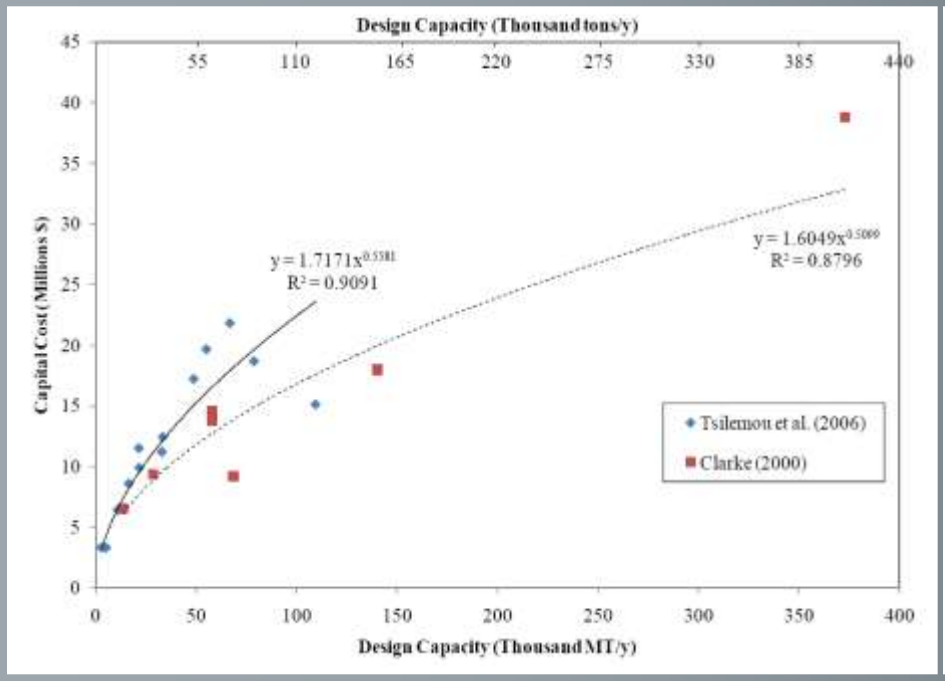
Trends in AD Design

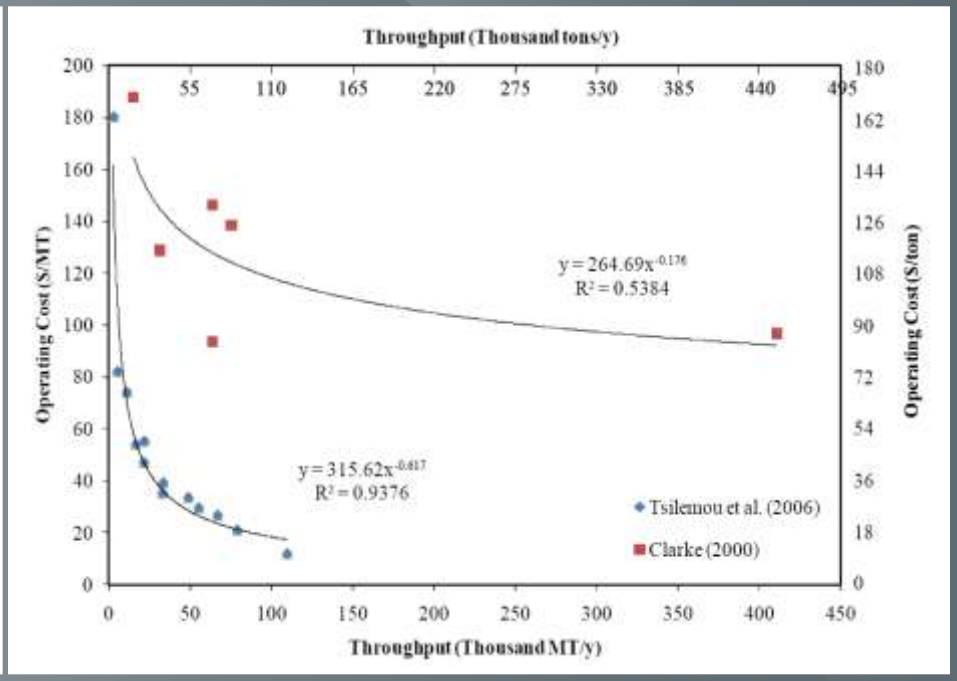




H. Hartmann and B.K. Ahring. Strategies for the anaerobic digestion of the organic fraction of municipal solid waste: an overview The Environmental Microbiology/Biotechnology Research Group, BioCentrum-DTU, Building 227, The Technical University of Denmark, DK - 2800 Lyngby, Denmark (E-mail: hwh@biocentrum.dtu.dk) Water Science & Technology Vol 53 No 8 pp 7–22 Q IWA Publishing 2006

AD Capital and Operating Costs





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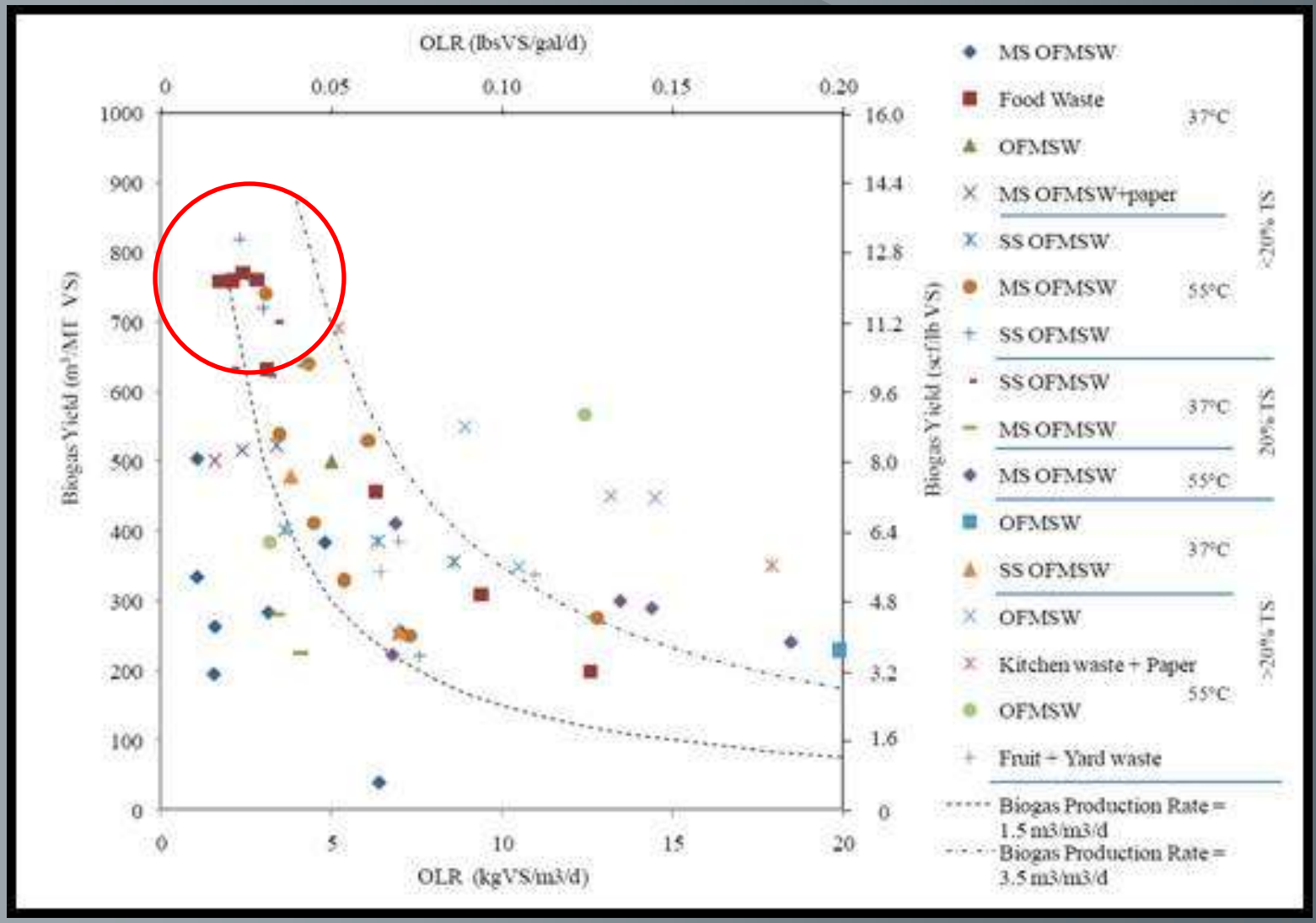
AD Biogas Production Potential



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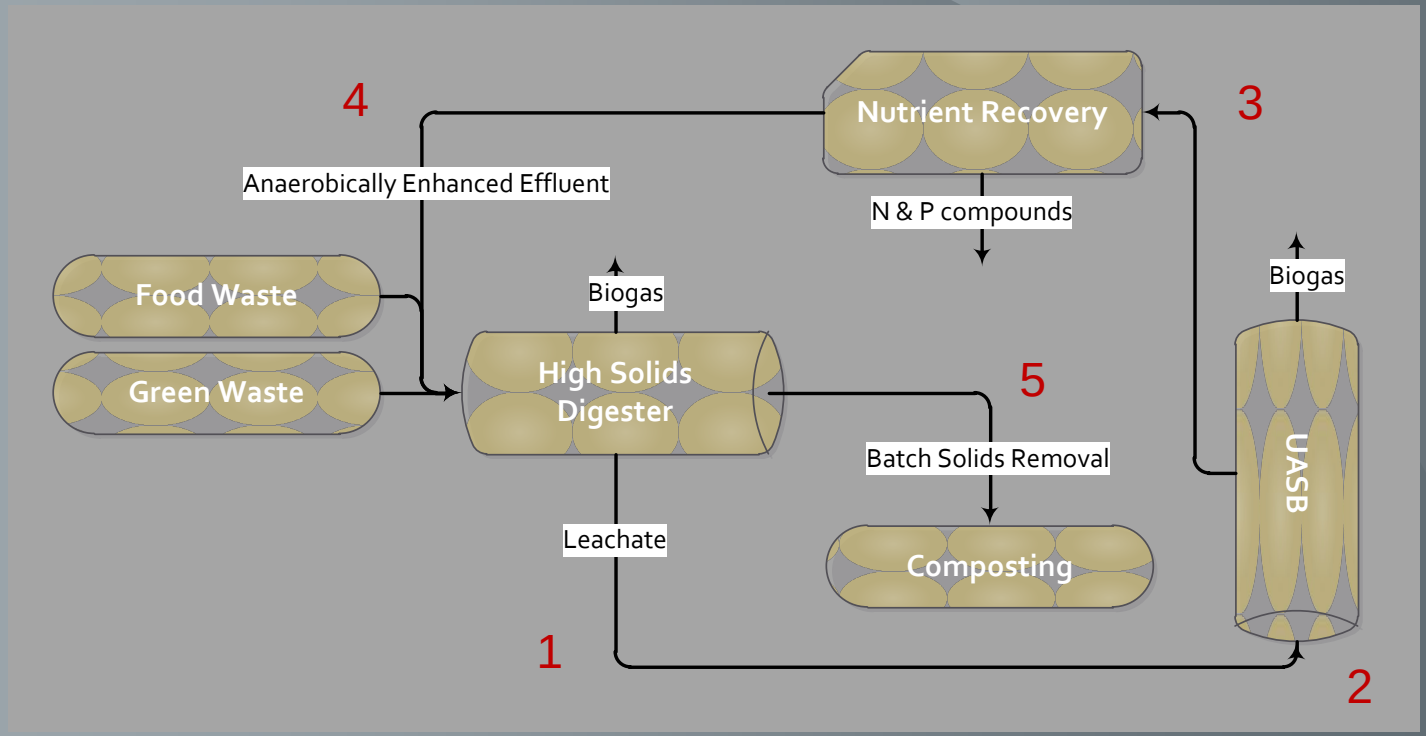
AD Case Study: Return on Investment

- Assumptions
  - 2.5 m^3 biogas/m^3 digester/day
  - 60% methane content in biogas
  - 20 day HRT
  - 300 MT/day
  - 9.5 ft^3 CH_4/kWh and $0.09/kWh
  - $20 million capital cost
- Electrical sales total $1.11 million
- **Estimated payback period of > 20 years**
- *Not economically viable in the U.S. -> will require technological advances

Present HSAD Concerns

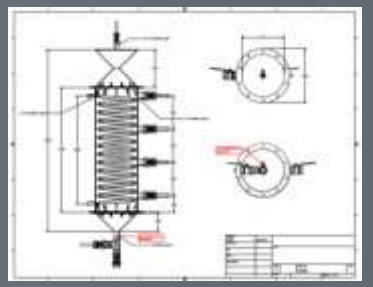
1. High parasitic pumping and mixing costs
2. Large digester volume increases capital cost
3. Difficult to incorporate nutrient recovery with present technology
4. Loss of operating efficiency due to product inhibition

Dual Digester, Single Phase Recycle Concept



1. Leachate pH controlled > 5.5
2. Low solids liquid stream with high VFA concentration
3. pH neutral high nutrient liquid with VFA removed
4. Return water plus active microbial population
5. No mechanical mixing and no solids pumping

Experimental HSAD System



Representative Food Waste Sample

- 70% Food Waste
- 30% Green Yard Waste
- Total Solids 25-30%

Preliminary Modeled Benefits

- Preliminary modeling of the WSU experimental system identifies an approach that can improve loading and biogas production rates over dry systems by 50%, while achieving comparable chemical oxygen demand and total solids reduction.
- Inclusion of a nutrient removal and recovery system increases the overall economic value of the system, producing 2.1 kg/ton of nitrogen and 3.72 kg/ton of phosphorus from food waste.
- Based on the modeling, the cost of treating organic waste with this system is estimated to be $1.08/kW-h compared to $1.55/kW-h calculated for an existing technology.
- Floor scale validation of modeling results is required and at the core of the present effort.

Producing Energy and Fertilizer from Organic Municipal Solid Waste: Enhancing hydrolysis and bacterial populations and mixing and thermodynamic modeling of new solid waste treatment technology

Ecology Publication Number 09-07-064

Experimental Plan

Tasks	2010				2011			
Preliminary AD design parameters estimated	X	X						
CAD Drawings provided to fabricator		X						
Experimental trials for food waste hydrolysis			X	X				
Experimental trials for dual digester AD system				X	X			
Dissemination of final results						X		

- Food Waste Hydrolysis
  - Saturation point
  - Leaching bed rate
  - Leachate composition
- Dual Digester, Single Phase System
  - COD and VFA reduction and CH_4 production
  - Determine process variables
  - Test with various feed stocks

Commercialization

- Complete floor scale testing June 2011
- Evaluate system to particular commercial applications
  - Potato solids – Potandon Foods
  - Decentralized commercial food – WisErg
  - Compost facility – Barr Tech Eco-Park
- Secure funding for pilot testing
  - California Energy Commission
  - SERTI
- Pilot testing June 2012

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  - Department of Biological Systems Engineering
  - The Gene and Linda Voiland School of Chemical Engineering and Bioengineering

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